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Have the new safety limits and the introduction of 5G technology increased the background of the electromagnetic field in the radio frequency range?

Abstract *It is rare to observe the impact of significant legislative changes related to the permissible safe limits on the background of electromagnetic field (EMF) intensities in the environment. This situation occurred in Poland at the turn of 2019 and 2020. At this time, the safety limits related to the intensity of EMF in the general public environment were changed. An additional factor that possibly influenced the environmental background of EMF was the gradual introduction of 5G technology and the reframing of certain bands used in telecommunications. All of these facts caused serious fears in a part of society concerning the potential and considerable increase in the intensity of environmental EMF. Performing another research on the impact of EMF on humans, measurements of the EMF background level were made at the beginning of 2020 and at the end of 2022. The article shows how the background of EMF has changed over almost three years at the place where the measurements were made.*

Streszczenie*. Rzadko można zaobserwować wpływ istotnych zmian legislacyjnych związanych z dopuszczalnymi bezpiecznymi limitami na tło natężeń pól elektromagnetycznych (PEM) w środowisku. Taka sytuacja miała miejsce w Polsce na przełomie 2019 i 2020 roku. W tym czasie limity bezpieczeństwa związane z natężeniem PEM w środowisku publicznym uległy zmianie. Dodatkowym czynnikiem, który mógł mieć wpływ na tło środowiskowe PEM, było stopniowe wprowadzanie technologii 5G i przeformułowanie niektórych pasm wykorzystywanych w telekomunikacji. Wszystkie te fakty wywołały poważne obawy części społeczeństwa dotyczące potencjalnego i znacznego wzrostu natężenia środowiskowego PEM. Wykonując kolejne badania nad wpływem PEM na ludzi, na początku 2020 roku i pod koniec 2022 roku wykonano pomiary poziomu tła PEM. W artykule pokazano, jak tło PEM zmieniło się na przestrzeni prawie trzech lat w miejscu wykonania pomiarów. (**Czy nowe limity bezpieczeństwa i wprowadzenie technologii 5G zwiększyły tło pola elektromagnetycznego w zakresie częstotliwości radiowych?**)*

Keywords: electromagnetic field, electromagnetic field safety limits, EMF, EMF impact on humans
Słowa kluczowe: pole elektromagnetyczne, limity bezpieczeństwa pola elektromagnetycznego, PEM, wpływ PEM na ludzi

Introduction

At the end of 2019, an amendment to the Law on Supporting the Development of Telecommunications Services and Networks was introduced in our country, which brought about several significant changes related to telecommunications development (Journal of Laws 2019, item 1815) [1].

The most significant controversy arose regarding amendments to the Environmental Protection Law, specifically related to permissible levels of electromagnetic fields (EMF) in the general environment. The responsibility for establishing these limit levels was transferred to the Minister of Health in consultation with the Minister of Information Technology. Consequently, a decree issued by the Minister of Health on 17 December 2019 has changed the permissible levels of EMF intensity in the environment (Journal of Laws 2019, item 2448) [2]. From January 1, 2020, the permissible levels, defined as safe, in the radio frequency range were aligned with EU Recommendation 1999/519/EC [3], which is applied in most European countries. For example, for frequencies above 2 GHz, the previous permissible level for the electrical component of 7 V/m was increased nearly nine times to 61 V/m while the permissible level of the power density changed 100 times, from 0.1 W/m^2 to 10 W/m^2). These changes considered by the general public to be unusually large, along with the planned introduction of 5G technology, have sparked concerns within certain societies about a potential significant increase in background levels of EMF in the environment, potentially adversely affecting the health of the population [4-6].

Let us add that the period between 2020 and 2023 coincided to a large extent with the Covid-19 pandemic, which significantly changed many areas of everyday life, including the approach to issues related to wireless telecommunications. This factor could possibly also influence the EMF background level due to changing demand for telecommunications services but also due to potential disruptions in the development of telecommunications infrastructure.

At the beginning of 2020 and at the end of 2022, research on the effects of artificially generated EMF on women's psychomotor abilities was conducted at the Faculty of Medicine of the Jagiellonian University Medical College [7]. The study required precise control over the generated EMF levels, as well as an assessment of the background EMF levels at the testing site. This research gave a unique opportunity to observe potential changes in EMF levels emitted by the telecommunication infrastructure in the experimental area, especially by mobile telephony base stations, but not only. The measurements were started at the beginning of a period when changes in background EMF levels were anticipated due to new regulations and the gradual implementation of 5G technology, as well as more than two years later. The same methods and equipment were used in both periods considered.

Materials and methods

The original projects aimed to investigate the impact of artificially generated EMF on psychomotor abilities [7]. The experiments were performed under double-blind conditions with and without the presence of higher intensity EMF. Subjects underwent computer tests to assess their concentration, reaction speed, perceptiveness, motor coordination, and decision-making speed while exposed to EMF with intensities exceeding typical environmental levels but equal to about half of the intensity considered safe in the moments when the experiments were prepared.

Both experiments required the evaluation of the background levels of EMF during the tests without the presence of the field, as well as before and after each patient's participation. Each background measurement extended from several minutes to several tens of minutes, enabling the collection of data of different radio frequency EMF intensity bands used by the telecommunications infrastructure in an enclosed room situated in the heart of a

city (Cracow, Poland inhabited by slightly less than 1 million inhabitants. The measurements were carried out at various times between 8:00 am and 7:00 pm within an educational building on St. Lazarus Street, which could be considered representative of a typical office setting.

For the 2020 dataset, 87 time slots, ranging from 3 to 63 minutes, were analyzed. In the case of the 2022 dataset, 131 time slots, ranging from one minute to 67 minutes, were subjected to analysis. The average levels of EMF intensities were compared for both experiments. Also, the daily time changes were studied for both stages.

An additional analysis covered the issue of changes in the intensity of the EMF background during the first period of the study, i.e., at the time when the greatest surge was expected. To check whether this increase has occurred, the average intensities of EMF in the first three quarters of 2020 were calculated separately. These calculations took into account measurements taken between 11 a.m. and 3 p.m., for which period the most numerous measurements were available.

The measurements were carried out using the ExpoM-RF exposimeter (Fields at Work GmbH, Zurich, Switzerland), which allows for selective determination of the electrical component of EMF across commonly used radio frequency communication ranges, including: cellular networks; the DECT system; the 2.4 GHz, 3.6 GHz, and 5 GHz bands; radio, and television. This device allows measurements within the frequency range of 50 MHz to 6 GHz, with a maximum measurable value of the electric field component of 6 V/m [8]. The background was evaluated beside the EMF beam generated by our system, so even in the second stage when the intensity was far above the device range the measurements were still reliable.

The measurements were taken at three-second intervals and the recorded data was digitally stored in XLS format files. We calculate the average intensity of the electrical component of the EMF originating from telecommunications infrastructure equipment (Down-Link). In particular, we excluded the field generated by mobile terminals (UpLink) from the presented analyses, recognizing that this field does not represent a constant background component at the studied location.

Data analysis was performed using MS Excel (Microsoft Corporation, Redmond, USA). For statistical analyses, the Stargraphix Centurion 19 package (Statgraphix Technologies Inc., Virginia, USA) was used. The Kolmogorov-Smirnov test was used to compare the results and it was assumed that the compared parameters were statistically different when $p < 0.05$.

Results

The average intensities of the electric component of the EMF in both studied periods were calculated from all measurements made. The average error of the mean was used as an estimator of the uncertainty of the measurement.

The average intensity of the electrical component of the EMF at the study site from February to July 2020 was 100.3 ± 1.9 mV/m and increased to 115.4 ± 0.8 mV/m in November/December 2022. This change is statistically significant ($p < 0.05$).

Part of the change in recorded background EMF levels is related to the operation of radio and television transmitters, not just telecommunication equipment. In the frequency range used for radio (FM), the average of 19.3 ± 0.7 mV/m in 2020 increased to 37.2 ± 1.0 mV/m in 2022. In the case of signals from terrestrial TV transmitters, a decrease was observed during the considered period from 17.11 ± 0.34 mV/m to 13.23 ± 0.08 mV/m.

Taking into account only sources related to mobile network infrastructure, there was an increase from 96.9 ± 3.5 mV/m to 108.5 ± 2.1 mV/m.

In the period analyzed of the first three quarters (Q1-Q3) of 2020, the average value of the intensity of the electrical component of the EMF was assessed to be the highest in Q1 and was equal to 112,3 ± 1,5 mV/m. In the second quarter, the average value was the lowest and was equal to 93,8 ± 4,3 mV/m. It increased in the third quarter to the value of 100,1 ± 1,4 mV/m, but did not reach the value of Q1. All observed changes are statistically significant. The average daily changes of EMF in the first three quarters of 2020 analyzed in two hour intervals are presented in Figure 1.

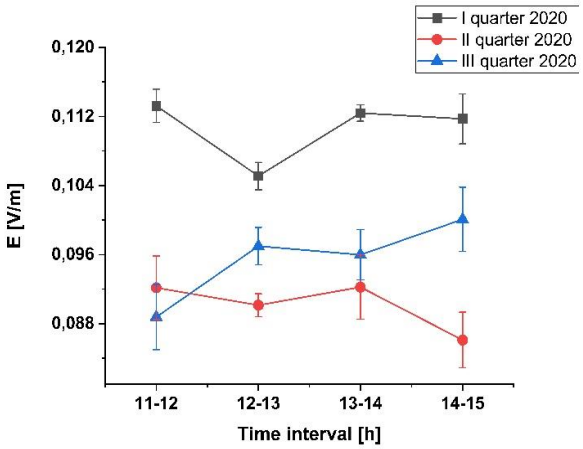

Fig. 1. Changes in total electromagnetic field strength (for all analyzed frequency bands) from 11 a.m. to 3 p.m. averaged for the first three quarters of 2020.

Discussion

The background level of EMF at the study site has increased over two years, but the results obtained indicate changes related to the natural evolutionary and gradual development of technology, rather than related to changes in the permissible levels of EMF in the environment or the sudden introduction of 5G networks. The observed increase in total EMF background intensity is on the order of 15% percent and is not proportional to the changes introduced in permissible levels. Recall that for some of the frequency ranges studied (higher than 2 GHz), the safety allowed levels increased from about 7 V/m to about 61 V/m, which is a change of 770%. Mobile network transmitters account for about 12% of the increase in the intensity of the electrical component of the EMF in the radio frequency bands, but they are the main source of the electromagnetic background component in both periods studied.

The analysis of the EMF strength in the first period just after the safety-permissible levels changes, i.e., in the first three quarters of 2020 did not show the monotonic increase as one would expect. The field strength decreased in the second quarter and slowly increased in the third quarter of 2020, reaching more or less the values measured in 2022. Small, albeit statistically significant, changes are caused by natural variability related to the variability of the seasons, gradual rearrangement of infrastructure to new conditions, or other changes, e.g., the gradual departure from analogue television in favor of digital solutions observed at that time or the impact of the Covid-19 pandemic.

It is well known that environmental EMF intensities are characterized by high temporal and spatial variability [5, 9-

11]. They are influenced by terrain, type of development, type of area (urban, non-urban), but also by time of day, season (abundant vegetation, or lack thereof) and many other factors [9-11]. The construction of the building (a reinforced concrete building in this case) significantly weakens the amplitude of the EMF, so the results of the measurements are significantly lower than if they were taken outside the building [9]. Certainly, the field strength observed in the open space in the area where the measurements were taken will be higher than described, but it will also certainly not even approach the permissible levels, even if we took into account the previous, superseded values.

During both periods studied, the EMF intensity values were obtained at levels of the order of 0.17% and 0.19% of the permissible values (new, after changes), respectively. These levels in simulations of the EMF intensity distribution available in the SI2PEM system [13] were determined to be less than 1% of the permitted limit. These results can be considered to be in agreement; however, it should be remembered that the results of the SI2PEM system simulations are performed for outdoor EMF intensity, while the values obtained in presented measurements are for indoor EMF intensity.

The only factor that could be included in the analysis based on the collected data was the temporal variation during the working day. Measurements were taken at different times of the day on weekdays. The graphs shown in Figures 1-4 show how the intensity of the electrical component of EMF in the radio frequency range of all sources (Figures 1 and 2), from FM radio (Figure 3) and from TV transmitters (Figure 4) varies during the day.

The variation observed for the Q1-3 period, in the 11 a.m. to 3 p.m. (Figure 1) is not so obvious when analysis considered two hour working day periods. Nevertheless, it can be observed if the analysis concerns the whole working hour analyzed in the one hour periods. The field intensity from all sources (Figure 2) depends on the time of day and is highest during typical working hours, while it is lower in the morning and evening [10]. For graphs showing the daily variation of intensity coming from radio and TV transmitters within the limits of measurement errors, the field strength does not change. This observation shows that the field intensity generated by cell phone base stations is higher in an area when the real demand for telecommunications services is also higher. There are more users in Krakow's downtown areas during business hours than in the morning and evening.

The undoubted disadvantage of the results described is that the data presented are obtained for only one selected location and that the measurements took place inside a building. Since the tests took place at convenient times for the volunteers participating in the project, the measurements were carried out relatively irregularly. As a result, different days of the week and different times of the day are represented by different numbers of measurements.

Another limitation of the presented results is the fact that they were obtained with the use of a not top-class and formally not calibrated exposimeter. For this reason, the presented absolute values of field strength can be questioned. However, the observed relative changes in the background of the EMF appear to be plausible.

A final limitation is the difficulty in assessing the impact of the Covid-19 pandemic on the results. On the one hand, the increase in demand for wireless telecommunications services may have led to an increase in the background of EMF, and, on the other hand, restrictions related to the pandemic time may cause some difficulties in the development of telecommunications infrastructure.

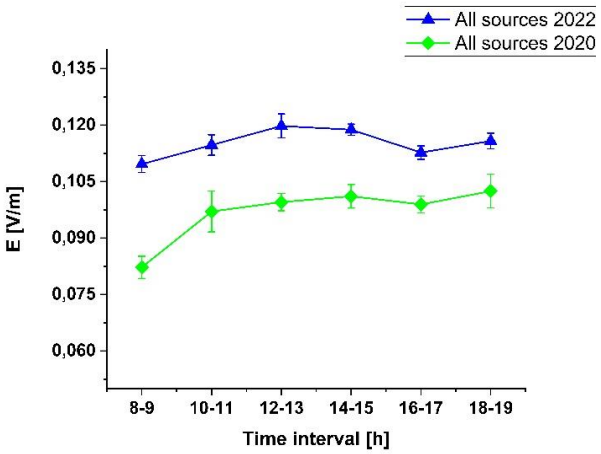

Fig. 2. Daily changes in the intensity of the radiofrequency component of the electromagnetic field measured at the described location. The results show the field strength from all emitting sources in the analyzed frequency range.

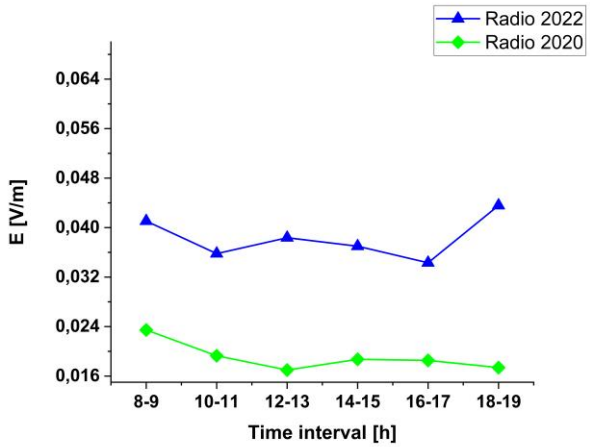

Fig. 3. Changes in working hours in electromagnetic field strength for the range used by FM radio transmitters.

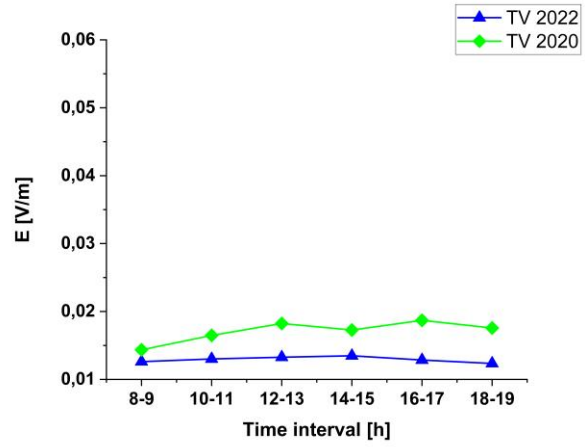

Fig. 4. Changes in working hours in electromagnetic field strength for the range used by TV transmitters.

Conclusion

Changes in law regulations regarding the increase of permissible levels of electromagnetic fields (EMF) in the general environment in Poland have provided a unique opportunity to study the relationship between exposure to EMF and established safety permissible limits.

Despite some drawbacks of the results presented, there is no doubt that the presented example supports the thesis that there was no drastic increase in the level of background of EMF, at least at the place where the measurement were performed. There is a question whether this conclusion could be generalized to the whole country, which could be concluded from other sources [13].

The EMF strength in the typical city site is far below the safe levels allowed. This remains in agreement with scientific reports from studies conducted in other countries that confirm that the limits are significantly overestimated relative to the intensity levels of EMFs from the base stations that actually occur in the environment [14, 15].

Environmental radiofrequency EMF comes from different kinds of sources (mobile telephony base stations, FM radio transmitters and TV transmitters) but at the moment the telecommunication infrastructure is the main source of the background EMF except from the mobile terminals not considered in this paper.

Finally, it can be concluded that the amount of energy emitted by EMF sources is rather dictated by technical considerations and economic calculations and not by the safety permissible limits defined by the law regulations.

Hopefully, the introduction of 5G will allow for very good quality communication without a significant increase in the intensity of EMF [16] but the veracity of this conclusion must be checked after the full introduction of this technology in Poland, taking into account the higher frequency bands that are still not available at the moment.

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